HYPOGENE SPELEOGENESIS – DISCUSSION OF DEFINITIONS

Y.V. Dublyansky[1]

Existing definitions of the term *hypogene karst* (hypogene speleogenesis) are not always consistent with the established meaning of the term hypogene in the Earth Sciences. They are commonly biased either toward geochemical or toward hydrogeological aspects of the phenomenon. It is proposed that hypogene karst is defined on the basis of the two properties: predominance of the deep-seated sources of aggressiveness of karst water, independent of the environment at the overlying or immediately adjacent surface; and recharge of soluble formation from below, independent of recharge from overlying or immediately adjacent surface.

THE TERM HYPOGENE IN EARTH SCIENCES

The term *hypogene* was first introduced in geological literature by Sir Charles Lyell, in an attempt to remove ambiguity in rock designation "primary" and "secondary", customary at the time. Lyell (1833) postulated that "*the hypogene rocks can only originate at great depths in the regions of subterranean heat.*" Subsequently, the term was re-introduced by Ransome (1913) for ore deposits and minerals; again, to confront the "primary-secondary" ambiguity (mineral, ore, mineralization, etc.). He also proposed the complementary term supergene for minerals "*deposited by generally downward moving and initially cold solutions*" (p. 153).

Presently, *hypogene* is rarely used to designate rocks (i.e., sensu Lyell), but most commonly refers to processes, minerals, ores, deposits, solutions, and the like (sensu Ransome). This can be illustrated by one of the earliest definitions of Bastin and Laney (1918): "*Solutions coming from great depth within the earth and having a general upward flow will therefore be termed hypogene and the work they accomplished hypogene mineralization.*"

Similar understanding is captured in modern reference sources, e.g. "*Hypogene is a term used only in the adjective form for any geological process genetically connected with deeper parts of the Earth's crust or for mineral, rock and ore formed beneath the surface of the Earth. It is an opposite term to supergene. ... Hypogene (= endogene) processes include tectonic, magmatic, metamorphic and hydrothermal processes, as well as the formation of various ore deposits. ... Hypogene ore deposits are formed under the influence of deep-seated endogene (= hypogene) geologic processes by the action of ascending solutions. Such solutions and conditions of ore formation are also called hypogene*." (Springer Reference)

DEFINITION OF HYPOGENE SPELEOGENESIS

Finding a good definition for a natural phenomenon is always a balancing act involving search for the most appropriate mix of the exactness and the generality. Because the term hypogene is so widely used in the Earth Sciences, it is important also that its meaning in karst studies is consistent with the conventional one.

As the subject of hypogene karst gained prominence over the last decades, two approaches toward defining it have emerged. These approaches can conventionally be classed as geochemical and hydrogeological ones.

In a geochemical approach, the emphasis is on the geochemical mechanisms, processes of dissolution, and sources of aggressiveness that lead to creation of karst cavities. For example, Worthington and Ford (1995), following Ford and Williams (1989), define hypogene caves as those formed "*by processes involving sulfate, sulfide, and/or thermal waters*" (p. 9). A more-general definition was proposed by Palmer (2000) who defined hypogenic caves as those "*formed by water in which the aggressiveness has been produced at depth beneath the surface, independent of surface or soil CO_2 or other near-surface acid sources.*"

The hydrogeological approach was introduced by Klimchouk (2007), who suggested that "t*he definition of hypogenic speleogenesis should rather refer to the source of groundwater, as it is a medium of transport of aqueous and nonaqueous matter and energy, a reactive agent and a major component of the speleogenetic environment*" (p. 6), and "*The systematic transport and distribution mechanism capable of producing and maintaining the required disequilibrium conditions is the groundwater flow system ... This is the single fundamental reason why the principal categories of karst and speleogenetic environments should be distinguished primarily on the basis of hydrogeologic considerations, rather than by the particular dissolutional mechanisms involved*" (p. 8).

Within the hydrogeological approach, hypogene karst is defined through its place and position in hydrogeological system, most commonly on the basis of its relationships with the recharge area at the surface. For example, Ford (2006) defines hypogenic speleogenesis as "*the formation of caves by water that recharges the soluble formation from below, driven by hydrostatic pressure or other sources of energy, independent of recharge from the over-*

[1]Institut für Geologie, Leopold-Franzens-Universität, Innrain 52, 6020 Innsbruck, Austria, juri.dublyansky@uibk.ac.at

lying or immediately adjacent surface" and Klimchouk (2007) postulated that the **only** main attribute of the hypogenic karst is its "*lack of genetic relationship with the groundwater recharge from the overlying surface*" (p. 6).

DISCUSSION

Karst is an undeniably hydrogenic process, and a hydrogeological approach in karst studies is therefore perfectly justified. Many concepts of the "mainstream" hydrogeology, such as the concept of the hierarchical character of hydrogeological systems for example are directly applicable to karst studies (Tóth, 1999; Klimchouk, 2007). There is, however, an important distinction, or rather, difference in focus, between the "classic" hydrogeology and the karst studies.

The former concerns itself primarily with the movement of water. Processes of water-rock interaction, although appreciated, do not occupy a central position in it. Aqueous geochemistry, the main branch of hydrogeology dealing with chemical effects of water-rock interaction, studies to what extent this interaction affects the water, but does not typically consider how it affects the rock. In contrast, in karst studies the effect of water-rock interaction on the rock (primarily, dissolution) is the sin qua non. In other words, without considering water-rock interaction (dissolution), hydrogeology remains hydrogeology. In contrast, taking out the water-rock interaction (dissolution) effectively annihilates the very subject of karst studies.

Because of this, it is my opinion that the balanced definition of the hypogene karst must integrate both approaches. Accordingly, the two defining properties of the hypogene karst are:

- Predominance of the deep-seated sources of aggressiveness of karst water, independent of the environment at the overlying or immediately adjacent surface; and
- Recharge of soluble formation from below, independent of recharge from overlying or immediately adjacent surface.

It is to be noted that, the notion of the "source of aggressiveness" is treated here in the most generic sense. For hypogene karst in carbonate rocks this role can be played by deep-seated acids. For rocks, which dissolve by simple dissociation, the very presence of unsaturated water can become a source of aggressiveness. The cooling of the upwelling water can be a source of aggressiveness for rocks having retrograde solubility (e.g., gypsum and calcite). And so on.

Importantly, the demonstrable lack of the deep-seated sources of aggressiveness in waters which enter the soluble formation from below, places speleogenesis in the "grey area," where its attribution to hypogene category becomes equivocal. A solution can be to designate karst (speleogenesis) which possesses both defining properties hypogene s*ensu stricto* (*s.s.*) and that which possesses only one of the defining properties – hypogene karst *sensu lato* (*s.l.*).

COMPLEMENTARY TERMS

The relevant complementary terms widely used in general geology and ore geology to define rocks, processes, minerals, mineral deposits are: *hypogene – supergene* (var. *hypergene*) and *endogene – exogene*. These "traditional" pairs of terms are semantically consistent. The first pair discriminates definienda in categories of relative position "above – below"

hypo- (from Greek) - under, below;

super- (from Latin) - above; over; beyond;

hyper- (from Greek) – over; above; cognate with Latin *super-*.

The second pair uses for discrimination categories "inside-outside"

endo- (from Greek) – within;

exo- (from Greek) – outside.

In karst lexicon, the pair *hypogene – epigene* (karst, cave, speleogenesis) is now entrenched. In contrast to the cases discussed above, the prefix *epi-* used to construct the term epigene has multiple meanings, some of which are not complementary to *hypo-*. Alternately, it can mean: on, upon, above, over (as in epicenter; epifluorescence); after (as in epilogue); in addition to (as in epiphenomenon); and near, close to (as in epicalyx). The term *epigenesis* is widely used in Earth Sciences, employing *epi-* in the second, temporal sense, along with a complementary *syngenesis*. Again, the latter pair is semantically consistent, referring to temporal categories "together, with" and "after".

A separate issue, specific to karst studies, is the similarity of the terms *epigene karst* and *epikarst*. The latter is defined as "*the uppermost weathered zone of carbonate rocks with substantially enhanced and more homogeneously distributed porosity and permeability, as compared to the bulk rock mass below*" (Klimchouk, 2004). Both terms employ suffix epi- in its spatial sense, with the distinction that the former refers to the "*origin from above*" while the latter refers to the "*location above.*" The epikarst is a part of the epigenic karst.

Summarizing, the term *epigene* (or epigenic) karst (speleogenesis) is not the most appropriate to define the opposite of the *hypogene* karst. The more appropriate antonyms would be *hypergene* or *supergene*.

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